

Planetary Protection for Human Exploration Missions: A Human Health Monitoring Perspective

Jennifer Law, M.D., M.P.H.

Johnson Space Center

March 24, 2015



2003



2015

Planetary Protection Engineer Duties

- Hardware readiness certification for Assembly, Testing, Operations, and Launch
 - Microbial reduction
 - Cleanroom assembly
- Flight hardware sampling, bioassays to verify cleanliness of spacecraft





NASA Procedural Requirements

NPR 8020.12D
Effective Date: April 20, 2011
Expiration Date: April 20, 2016

COMPLIANCE IS MANDATORY

Planetary Protection Provisions for Robotic Extraterrestrial Missions

Mission PP Category

I (Any)

II (Any)

III (Flyby, Orbiter)

IV (Lander, Probe)

V "Unrestricted Earth Return"

V "Restricted Earth Return"

Implementation Requirements

Documentation only.

Documentation only.

Impact avoidance and/or contamination control including: cleanroom assembly, microbial reduction, and trajectory biasing.

Impact avoidance and contamination control including: cleanroom assembly, microbial reduction, trajectory biasing, organics archiving.

As appropriate for the specified PP category of the outbound mission. No inbound PP requirements.

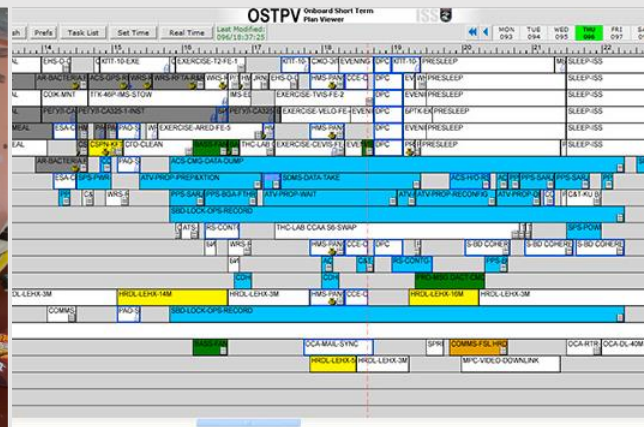
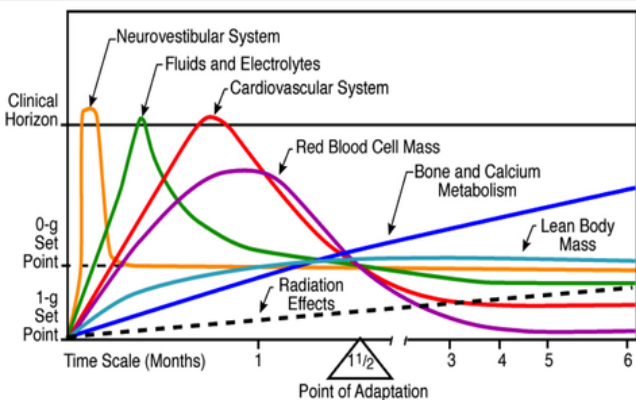
Impact avoidance and contamination control including: clean room assembly, microbial containment of sample, breaking chain of contact with target planet, sample containment and biohazard testing in receiving laboratory (continuing monitoring of project activities, preproject advanced studies and research, as needed).

Flight Surgeon Duties

Provide the medical support necessary for astronauts to perform their required duties to assure mission success

- Selection and certification
- Assigned crew—preflight, inflight, postflight
- Current mission operations
 - ISS Health Maintenance System
 - Suite of hardware to study eye anatomy and function on orbit
 - Correlation between chronically elevated CO₂ levels in microgravity and crew symptoms
- Future human spaceflight programs
 - Effects of the 8 psia / 32% O₂ Atmosphere on the Human in the Spaceflight Environment
 - IAA Study “Medical Support for an International Human Expedition to Mars”

What Flight Surgeons Think About



Preflight Health Stabilization Program

- 14-day quarantine for crew and supporting personnel
- Crew contacts
 - 3-day observation period prior to direct crew contact
 - Medical screening





Postflight



Humans are not robots

“Human missions will carry microbial populations that will vary in both kind and quantity...It will not be practicable to specify all aspects of an allowable microbial population or potential contaminants at launch.”

COSPAR Planetary Protection Policy 2011

- Microbial variations
 - Human metabolism
 - Dynamic health status
 - Altered microbiome during spaceflight missions
 - Trash from food packaging, medical supplies, etc.
 - Regenerative life support systems (plants)
- Procedures – human factors need to be considered
 - Crew time / crew duty day
 - Training retention
 - Task monotony vs. task saturation

No human spaceflight version of NPR 8020.12D yet

- ✓ • Impact avoidance
- Contamination control including
 - • Cleanroom assembly
 - ✗ • Microbial reduction
 - ✗ • Trajectory biasing
 - • Organics archiving
- Additional Category V requirements (Restricted Earth Return)
 - ✗ • Microbial containment of sample
 - ✗ • Breaking chain of contact with target planet
 - • Sample containment and biohazard testing in receiving laboratory

c. This document is specifically not applicable to the following:
(1) terrestrial (Earth-orbital) missions.
(2) human missions, except for robotic planetary missions launched using manned spacecraft.



An Evolvable Mars Campaign

Jason Crusan

Director, Advanced Exploration Systems



THERE & BACK

- The ability to launch a very powerful rocket
- High-reliability spacecraft systems
- Size requirements of crew capsule
- Validation of performance of SLS and Orion in the deep space environment (*hotter, colder, radiation*)
- Deep space navigation
- Rendezvous and docking
- Life support systems
- High speed re-entry

HAPPY & HEALTHY

- Air, water, food
- Waste containment
- Psychological impact
- Low- / no-gravity
- Medical emergencies
- Bone loss
- Radiation
- Ocular degeneration
- Hygiene

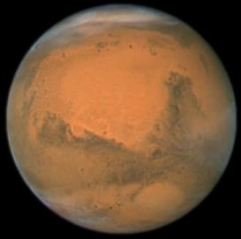
WELL EQUIPPED & PRODUCTIVE

- Sample handling
- Microgravity operations
- Space suits
- Advanced training and tools
- Mission planning
- Situational awareness and decision making
- Crew relationships

“The intent of this planetary protection policy is the same whether a mission to Mars is conducted robotically or with human explorers.”

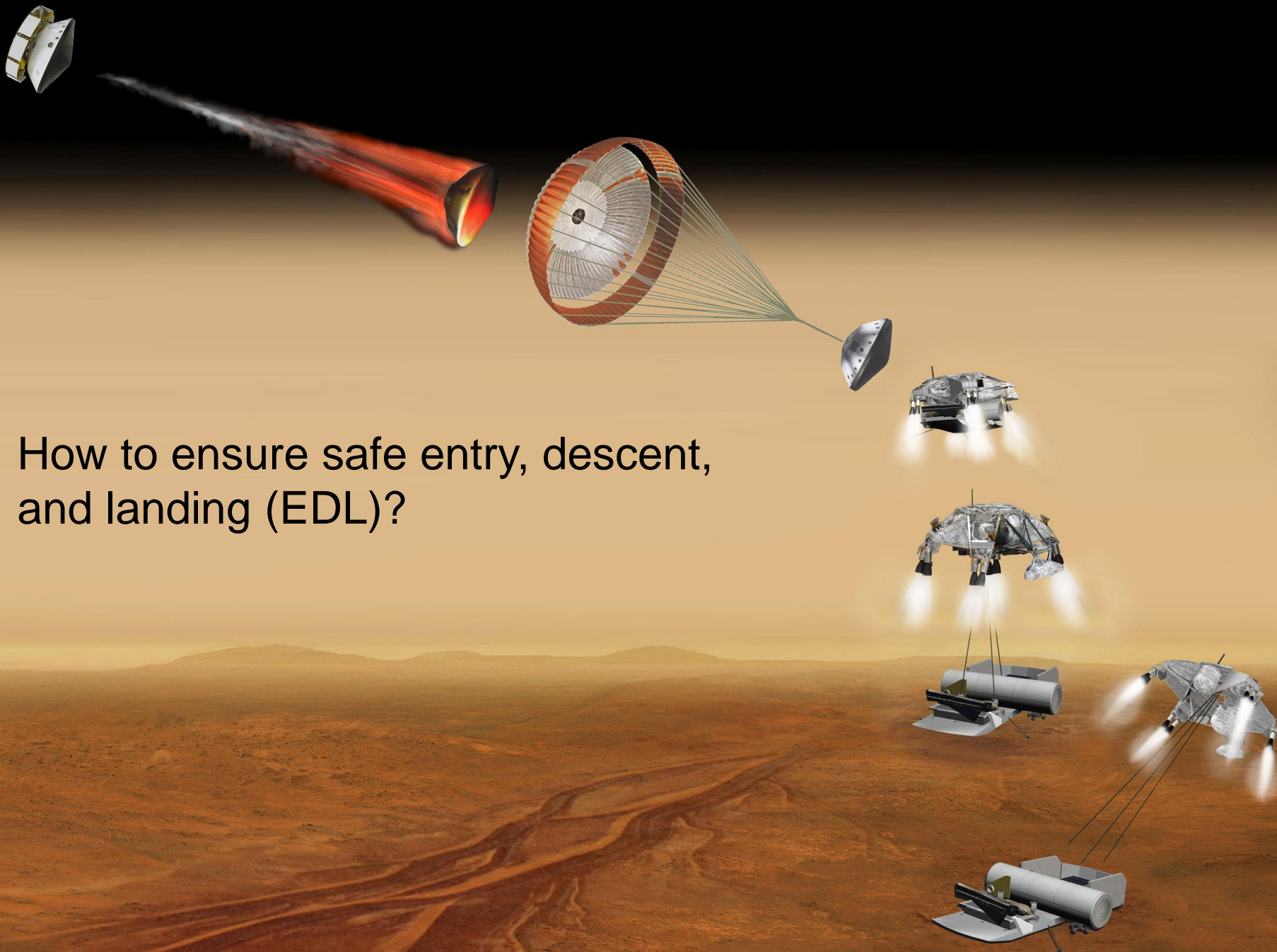
COSPAR Planetary Protection Policy, 2011

Some Questions...



- What crew selection criteria?
- Crew composition—Physician? PPO?
- Risks to crew health over the course of a Mars mission?
 - Changes to microbiome, immune system
 - Implications for antibiotics and treatment (e.g., delayed wound healing)
 - Unknowns
- How to keep crew healthy? Monitor health?
- What does preflight quarantine entail?





How to ensure safe entry, descent,
and landing (EDL)?



Mars environmental hazards to crew health? How to mitigate?

- Physical—0.38 G, dust, regolith
- Chemical/toxicological—CO₂, hexavalent chromium
- Microbiological?

What in-situ resources are available?

How to ensure safe for consumption?

Waste management?



The Trash We've Left on the Moon

MEGAN GARBER | DEC 19 2012, 2:17 PM ET

<http://www.theatlantic.com/technology/archive/2012/12/the-trash-weve-left-on-the-moon/266465/>

“Buzz Aldrin and Neil Armstrong alone left more than 100 items on the Sea of Tranquility”

“Here is a rough (and only partial) inventory of the stuff mankind has left on the moon”:

- more than 70 spacecraft, including rovers, modules, and crashed orbiters
- 5 American flags
- 2 golf balls
- 12 pairs of boots
- TV cameras
- 96 bags of urine, feces, and vomit
- various hammers, tongs, rakes, and shovels
- utility towels
- used wet wipes
- personal hygiene kits
- empty packages of space food



Sample handling?
Sample analysis?
Life detection?

What about contingencies?

- Fire
- Rapid depressurization
- Toxic atmosphere
- Trauma
- “Potential contact with a martian life-form”? (COSPAR 2011)

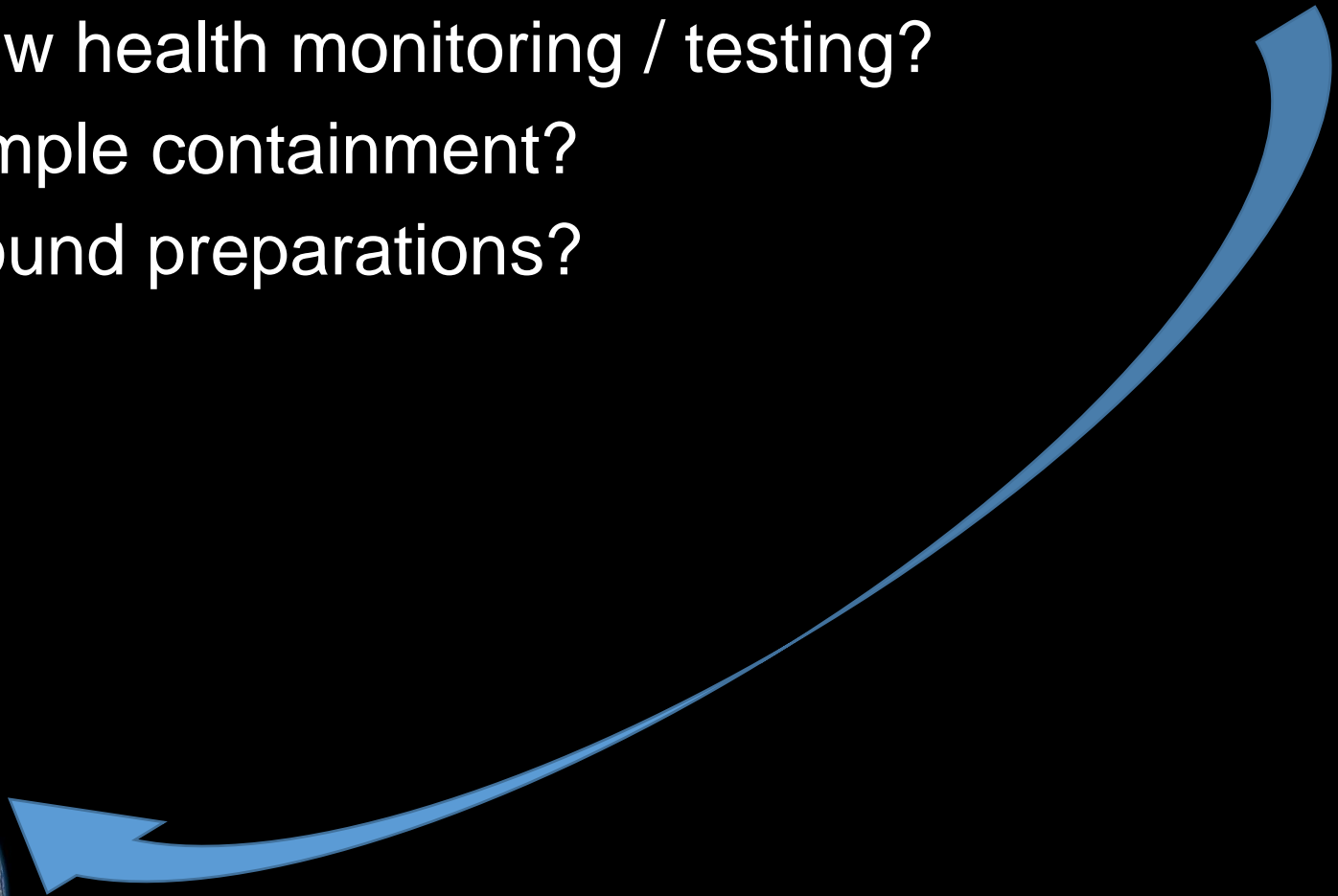
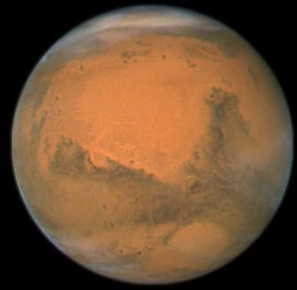


How to ensure safe ascent
and Earth return?

What to bring back, and
how?



Crew health monitoring / testing?
Sample containment?
Ground preparations?





Postflight quarantine – back contamination, “reverse contamination”

- Where, how long, what to safeguard against?
- How to distinguish “normal” postflight conditions from Mars-related illnesses—non-contagious stimuli (e.g., dust) vs. potentially contagious Martian life?
- Monitoring, testing?



Evolutionary Capabilities



EARTH RELIANT

Return to Earth: hours

EARTH-BASED SUPPORT: HIGH
Mission Duration:
6-12 months

Staying Healthy

Spacecraft Life Support Systems

- Developing onboard life support systems for long-duration missions

Human Health and Performance

- Studying space environment health risks and testing solutions

Autonomous Medicine

- Developing integrated medical capability and crew-reliant medical care

Environmental Monitoring

- Testing on-board environmental monitors with ground validation

Advanced Space Suits

- Testing next-generation space suits



PROVING GROUND

Return to Earth: days

EARTH-BASED SUPPORT: LIMITED
Mission Duration:
1-12 months

- Validating onboard recycling and regenerating life support systems without resupply

- Applying health and performance risk mitigation techniques

- Testing semi-autonomous integrated medical capability and crew-reliant medical treatment

- Demonstrating onboard environmental monitoring systems (no sample return)

- Demonstrating advanced space suits in deep space



EARTH INDEPENDENT

Return to Earth: many months

EARTH-BASED SUPPORT: NEGLIGIBLE
Mission Duration:
2-3 years

- Living and working in spacecraft that must fully support crew for years

- Living in space for years while maintaining crew health and performance

- Autonomous medical capability and medical crewmember for diagnosis and treatment

- Monitoring crew environment for hazards, eliminating environmental emergencies

- Conducting EVAs in unprecedented planetary environments

Human Health and Performance



EARTH RELIANT
Return to Earth: hours

- Studying space environment health risks and testing solutions



PROVING GROUND
Return to Earth: days

- Applying health and performance risk mitigation techniques



EARTH INDEPENDENT
Return to Earth: many months

- Living in space for years while maintaining crew health and performance

Ongoing ISS Research (1 Yr Mission)

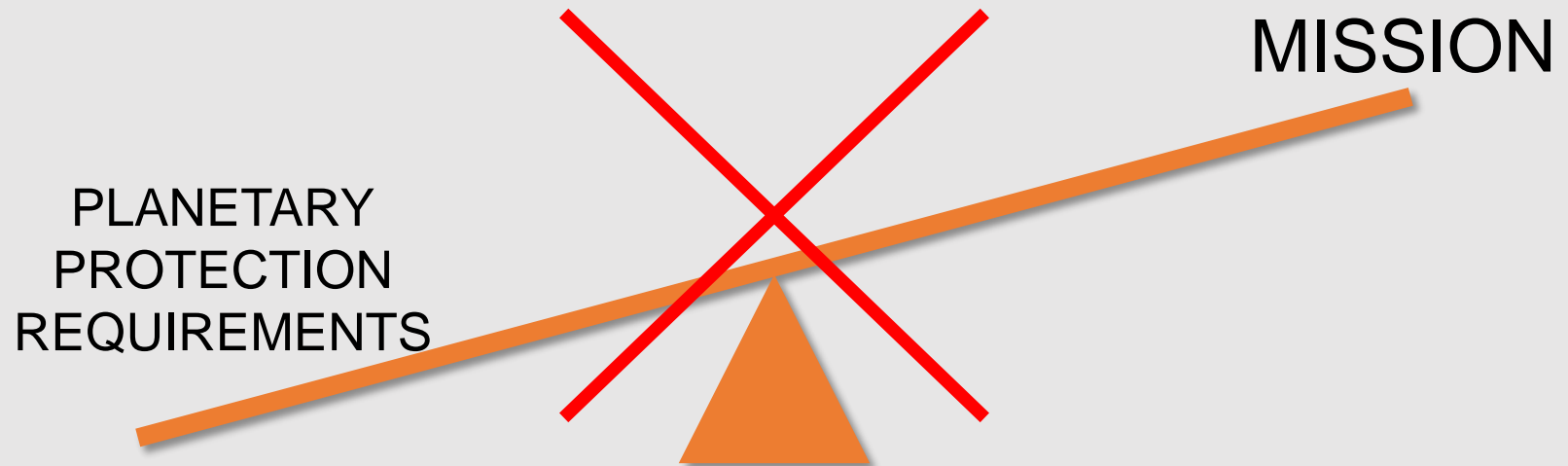
- Microbe-IV (Microbiological monitoring in the International Space Station-KIBO) - JAXA
- Microbial Observatory-1 (Microbial Tracking Payload Series) - NASA
- Microbiome (Study of the Impact of Long-Term Space Travel on the Astronauts' Microbiome) - NASA
- Multi-Omics (Multi-omics analysis of human microbial-metabolic cross-talk in the space ecosystem) - JAXA
- Plant Habitat (Plant Habitat Demo) - NASA
- Salivary Markers (The Effects of Long-Term Exposure to Microgravity on Salivary Markers of Innate Immunity) - NASA
- TripleLux-A (Gene, Immune and Cellular Responses to Single and Combined Space Flight Conditions - A) - ESA
- VIABLE ISS (eValuatlon And monitoring of microBiofiLms insidE International Space Station) - NASA

Opportunities for Collaboration Between Space Medicine and Planetary Protection

- Microbial characterization, monitoring, and control
 - Crew health / planetary protection bioburden
 - Preventing back contamination
 - Preventing reverse contamination
- Better understanding of biochemical nature of planetary materials
 - Regolith and dust
 - Ingredients for in situ resource utilization (e.g., water)
- Efficient and effective protocols
 - Sample handling
 - Health stabilization/quarantine
 - Contingency plans
- Education of stakeholders (engineering, science communities)

“Planetary protection goals should not be relaxed to accommodate a human mission to Mars.”

COSPAR Planetary Protection, 2011



Challenges

- Gain sufficient knowledge, in time to...
- Define operational constraints and requirements related to planetary protection
- Incorporate PP requirements early in the design process
- Prioritize PP requirements against all other program requirements – without overburdening
- Develop operational procedures / training
 - No experienced cadre
- How to ensure commercial/private entities do the same?



Conclusion

- Planetary protection for human exploration missions will be very challenging
- Paradigm shift required
- What is acceptable?
- Need to develop requirements and protocols that are feasible within the context of the most complex spacecraft/mission ever planned
- Offer strategies to mitigate risks to mission success